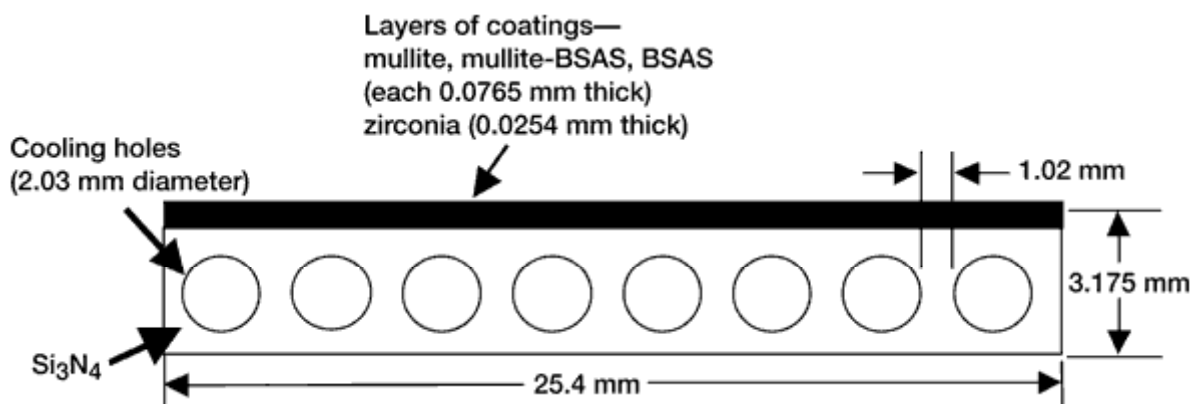


Thermal Response of Cooled Silicon Nitride Plate Due to Thermal Conductivity Effects Analyzed

Lightweight, strong, tough high-temperature materials are required to complement efficiency improvements for next-generation gas turbine engines that can operate with minimum cooling. Because of their low density, high-temperature strength, and high thermal conductivity, ceramics are being investigated as materials to replace the nickel-base superalloys that are currently used for engine hot-section components. Ceramic structures can withstand higher operating temperatures and a harsh combustion environment. In addition, their low densities relative to metals help reduce component mass (ref. 1). To complement the effectiveness of the ceramics and their applicability for turbine engine applications, a parametric study using the finite element method is being carried out.

The NASA Glenn Research Center remains very active in conducting and supporting a variety of research activities related to ceramic matrix composites through both experimental and analytical efforts (ref. 1). The objectives of this work are to develop manufacturing technology, develop a thermal and environmental barrier coating (TBC/EBC), develop an analytical modeling capability to predict thermomechanical stresses, and perform a minimal burner rig test on silicon nitride (Si_3N_4) and SiC/SiC turbine nozzle vanes under simulated engine conditions. Moreover, we intend to generate a detailed database of the material's property characteristics and their effects on structural response. We expect to offer a wide range of data since the modeling will account for other variables, such as cooling channel geometry and spacing. Comprehensive analyses have begun on a plate specimen with Si_3N_4 cooling holes.

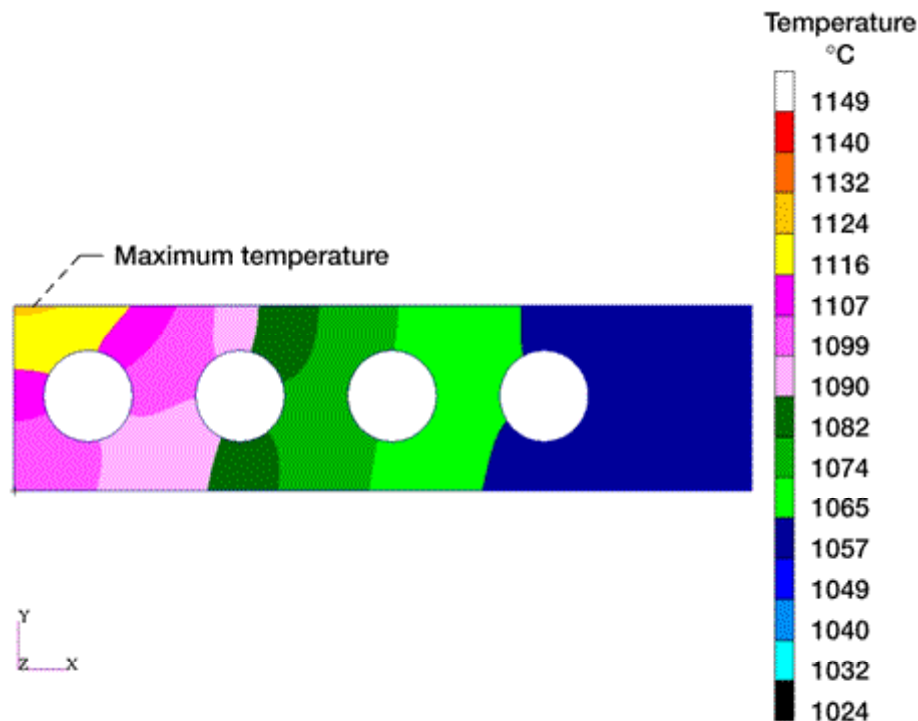


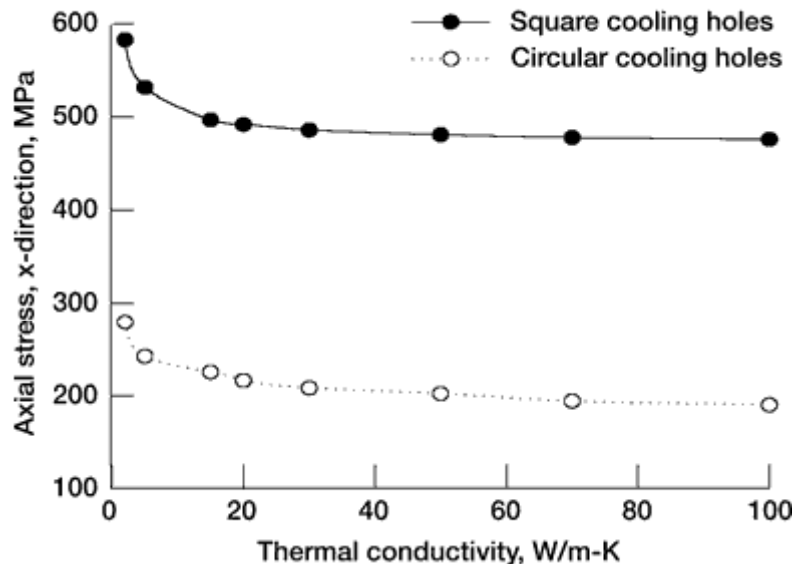
Monolithic Si_3N_4 cooling-panel cross section.

Long description of figure 1 Illustration showing eight 2.03-mm-diameter cooling holes spaced 1.02-mm apart on a 3.175-mm-wide, 25.4-mm-long Si_3N_4 plate, along with the layers of coatings--0.0765-mm-thick layers of mullite, mullite-BSAS, and BSAS, and a 0.0254-mm-thick zirconia layer.

Two-dimensional finite element analyses were performed in the form of a parametric study wherein heat transfer and stress analyses were conducted under steady-state conditions. The calculations were made under linear elastic conditions where the behavior of the material was defined by two material constants: Young's modulus and Poisson's ratio. The preceding sketch shows the geometry of the silicon nitride plate with cooling holes. The test specimen consists of four layers of coating and the silicon nitride substrate arranged in the following order: a top layer of mullite, a second layer of combined mullite and 20 wt% BSAS (barium strontium aluminosilicate), a third layer of BSAS, and a fourth layer of zirconia.

The next figure shows a typical temperature distribution generated by the ANSYS finite-element-analysis code. Convective flame impingement was imposed over one quarter of the top of the plate while convective cooling was imposed at the bottom of the plate and inside the cooling channels. The results indicate that the maximum temperature is at the middle section of the plate as anticipated. The final figure represents the stress variations due to thermal conductivity changes and cooling channel size and configuration. This shows that the stress decreases as the thermal conductivity increases and that lower stresses are reported for the circular channel configurations. Furthermore, the material temperature can be reduced substantially depending on the cooling channel configuration and the boundary conditions applied. The analytical efforts performed here are expected to assist greatly in ongoing burner rig testing research and activities. Additional details regarding this work can be found in reference 3.





Axial stress for the silicon nitride cooling panel along the x-axis as a function of the thermal conductivity with cooling for two different cooling holes configurations.

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